confronted by the geodetic problems which they present. The highest geological authorities express doubts as to how mountains have been upraised, and geological theorists differ widely.

In my recent paper I suggested, with diffidence, the hypothesis that the long belt of Indus-Ganges alluvial plains was concealing a deep crack in the subcrustal shell of the solid earth, and that the Himalaya mountains had been crumpled up by the opening of this crack in the solid globe.

When a large mass of heated rock, or ore, or glass is cooling, its surface is apt to crack; we never see the core of any such mass shrink away from the outer shell and leave the outer shell too large and unsupported, as is often assumed to be happening in the case of the earth.

Are geologists quite sure that the earth's outer shell has not been cracking, and that the cracks are not hidden from our sight by silt? Would not the cracking of a solid globe provide a sufficient mechanical force to elevate mountains?

The earth's rotation is slowing down; the equatorial protuberance of rock is constantly straining to move polewards.

Throughout the whole length of the Indus-Ganges belt of plains earthquakes are frequently occurring, and what can be causing these earthquakes, if not the splitting asunder of the solid globe beneath?

At both extremities of the Indus-Ganges belt deep narrow submarine cañons exist extending far out to sea; they are known to sailors as "swatches." What are these swatches, if not the surface indications of a subcrustal crack?

In the review in NATURE my hypothesis is dismissed without any specific objection to it being raised. I am not wedded to it, and I should welcome its dismissal, if I thereby learnt its errors. But I am disappointed to see it rejected merely because my critic has himself accepted the "floating crust" hypothesis.

The reviewer has accepted as true the hypothesis of the Rev. Osmond Fisher. According to this hypothesis the solid crust of the earth is of limited thickness and floats upon a liquid magma of greater density. This assumption of a liquid substratum appears to me to be opposed to the views of the great majority of geological writers. So far as I am able to judge, the weight of the evidence seems largely in favour of a solid globe.

Furthermore, Mr. Fisher has to assume that as the central core of the earth cools down, the outer crust is left unsupported owing to the core's contraction ("Geology of India," R. D. Oldham, p. 471). This assumption of a cooling core contracting away from its shell seems to me to be more difficult to justify than the assumption of a cooling shell becoming too small for its core.

But let me descend from these great assumptions to actual geodetic figures.

Mr. Fisher assumes that the crust floats in the dense liquid, just as ice floats in water. Each mountain rising from the upper surface of the crust has a corresponding protuberance extending downwards from the lower side of the crust. The buoyancy of a protuberance suffices to support the weight of the corresponding mountain above it.

If h = height of a mountain, and if d = depth to which its protuberant root extends downwards into the liquid, then, according to Fisher, $d = 9{\cdot}6 \times h$.

Now let me apply this hypothesis to the mountains of India. All these mountains are assumed to be buoyed by subcrustal protuberances of lower density than the magma, but the protuberances extend downwards to different depths, which are proportional to the several mountain heights.

Mountain	Height of mountain above crust = h Miles	Depth of protuberance below crust = d. Miles
Tibet plateau	3	29
Himalayan range	4	38
Vindhyas	0·6	5

Let us suppose a plumb-line to be suspended near the foot of a mountain, and let us suppose that the mass of this mountain is compensated by a deficiency of density underlying it below the crust. If that deficiency of density be wholly concentrated near sea-level, it will entirely compensate the attraction of the mountain mass, and the plumb-line will hang vertically. But if that deficiency of density be distributed to a great vertical depth, it will not compensate the mountain's attraction, first, because of its greater distance in depth from the plumb-line, and secondly, because its resultant action is more inclined to the horizontal.

If a mountain (Himalayan) is four miles high, and if its protuberance extends downwards to a depth of thirty-eight miles, the geodetic observer would report:—"There is distinct evidence of compensation, but the compensation is by no means complete."

If, however, a mountain (Vindhyan) is 0·6 mile high, its compensation would take place within five miles of the crust, and the observer would report:—"The compensation is here more complete than in the case of the higher mountain."

Similarly a pendulum observer at a station (Himalayan) two miles high will (according to the Fisher hypothesis) not find the same degree of compensation as he will at a station (Vindhyan) half a mile high. The underlying deficiency of density will in each case have a retarding effect on the pendulum, but at the Himalayan station the deficiency reaches downwards nineteen miles into the liquid, whilst at the Vindhyan station the deficiency only extends five miles downwards.

According, then, to the "floating-crust" hypothesis our plumb-line and pendulum observers should find the attraction of small mountains more completely compensated than the attraction of high mountains. But what are the results of actual observations? Both the pendulum and plumb-line observers find the attraction of the Himalayas to be largely compensated, whilst the Vindhyan mountains are not compensated at all. Actual results of observation are in direct opposition to the "floating-crust" hypothesis.

Mr. Hayford has stated that the "floating-crust" hypothesis is not true for the United States of America ("Figure of the Earth and Isostasy," p. 164), and in my opinion the evidence is sufficient to show that this hypothesis is not true for India.

S. G. BURRARD.

Surveyor-General's Office, Dehra Dun, March 29.

As an officer of the Survey of India, employed for many years in determining deflections of the plumb-line and variations in the intensity of gravity, I was interested to find in the article which appeared under this heading in NATURE (No. 2261, vol. xc., February (27) reference to the hypothesis suggested in 1904 by the Rev. O. Fisher as to the nature of mountain compensation, and the statement that this hypothesis goes far to explain the deflections of the plumb-line observed at the foot of the Himalayas and in the Gangetic plain. The article states that, according to Mr. Fisher's hypothesis, "the crust is of uniform density, the isostatic compensation being obtained by a variation in thickness," and that, on this hypothesis, Mr. Fisher "finds that the attraction of the visible range combined with the negative attraction of the downward protuberance should give a northerly deflection of about 24″ at the foot of the hills, of about 2″ at sixty miles away, and a southerly deflection of about 2″ at the farther edge of the plains. These results appear to be in very fair accord with the observations. . . .”

This statement is liable to convey a wrong impression. We are given to understand that the effects of the visible mountain mass and the downward protuberance are sufficient to explain the observed phenomena. The facts stated below will show how far this is correct. In addition, the article referred to makes no mention of an important feature of the Rev. O. Fisher's hypothesis. We are not told that part of the deficiency of mass which compensates the visible mountain range is supposed to be, not under the range, but under the plains. Mr. Fisher's hypothesis is not one of simple isostatic compensation, but involves the horizontal displacement of part of the compensating deficiency.

Mr. Fisher's investigations were published in *The Phil Mag.* of 1904, in an article which your reviewer suggests has been overlooked by Col. Burrard in his paper, “The Origin of the Himalaya Mountains: a Consideration of the Geodetic Evidence.” As regards the overlooking of Fisher's investigation, it will be sufficient to point out that it was included, at Col. Burrard's own request, as an appendix to Professional Volume xviii., “Astronomical Latitudes and Deflections of the Plumb Line,” published by the Survey of India in 1906. Also on p. 5 of Col. Burrard's paper under reference, we find the hypothesis of horizontal displacement of compensation discussed and rejected.

Before discussing Fisher's investigation, let me state the facts that require explanation. At the eastern end of the Himalayas are found northerly deflections of 46″, at a point about five miles north of the foot of the slope, and of 1″ at a meridional distance of twenty miles south of the slope. The variation of deflection in the twenty-five miles is 45″. In the central Himalayan region we find 38″ north at a few miles north of the foot of the slope and 5″ south at a meridional distance to the south of 112 miles, the variation here being 43″ in 112 miles. In the western Himalayas, in the meridian of Dehra Dun, deflections occur of 31″ north at the foot of the hills, and of 1″ north at a meridional distance of fifty-six miles. Here the deflections change by 30″ in fifty-six miles.

Thus, in a strip of country from thirty to 100 miles wide, lying immediately at the foot of the Himalayan slope, there is found a very rapid variation in the deflection of the plumb-line in the meridian. But while the variation is large, the average deflection over this tract is small, rather less than 20″ north. The observed variation of deflection is greater than that due to the visible Himalayan mass considered entirely uncompensated, and it might seem that we must admit this complete want of compensation of the hills in combination with a deficiency under the plains. Here, however, we are opposed by the evidence of the deflections themselves. Though we find that the observed variations of deflection are greater than if compensation did not exist, the observed deflections themselves are much smaller.

Now, Mr. Fisher, in his paper of 1904, investigated the deflections at three points on the meridian of Kalianpur. One of these lies at the foot of the Himalayan slope, and Mr. Fisher correctly takes Dehra Dun as representing this point. A second point, sixty miles from the slope, is represented by Kaliana, while the third point is 293 miles from the foot of the slope. This point is considered to represent Kalianpur. Kalianpur, however, is about 420 miles, measured on the meridian, south of Dehra Dun. The point 293 miles from the foot of the slope corresponds more nearly with a point between Usira and Kesri.

The observed phenomena which Mr. Fisher had before him were a change of deflection, amounting to 30″, in the sixty miles between Dehra Dun and Kaliana, and an average deflection in this interval of 16″; a change of 43″ between Dehra Dun and Kesri, with an average deflection of 16″.

Considering Fisher's investigation first from the mathematical point of view, we find that the theoretical plumb-line deflections are calculated for three points only, while his formulæ involve several unknowns, thickness of crust, crustal density, ratio of crustal to subcrustal density, the degree of compensation which, taken into consideration with the ratio of densities, determines the depth of the mountain root, the deficiency of mass underlying the plains and the area over which this is distributed. Obviously more than one set of suitably adjusted values of these unknowns will bring the formulæ into accord with the observed facts. The agreement, if such agreement did exist, of Fisher's calculated quantities with the observed deflections would be interesting, but it would not prove the correctness of his hypothesis.

Mr. Fisher calculated the theoretical deflections on two hypotheses, neglecting the effects of sphericity. In the first the visible mountain range is compensated by a deficiency of mass vertically below it. The results of this calculation are exhibited on p. 17 of *The Phil. Mag.* for January, 1904. The theoretical change of deflection over the sixty-mile interval is found to be 15·5″ in a plane at right angles to the range, or about 12″ in the meridian, with an average deflection of about 6·5″ in the meridian. These calculated quantities of 12″ and 6·5″ correspond to the observed 30″ and 16″. In calculating the effect at 293 miles from the slope, evidently an error has crept into Mr. Fisher's computations. The residual deflection is stated to be away from the mountain range. This is an impossibility where sphericity is neglected. The positive attraction of the visible mass and the negative attraction of the compensating root only become equal at an infinite distance from the mass. In a later paper, dated April, 1904, other figures are given for the deflection at the south of the plains, making the theoretical difference between deflections at the foot of the slope and at the south edge of the plains about 17″, with an average deflection of 10″ against the observed 43″ and 16″.

It is evident that “the attraction of the visible range, combined with the negative attraction of the downward protuberance,” fails to give theoretical effects in accord with the observations.

Mr. Fisher then modified his first hypothesis, and it is this modification that has been lost sight of by the reviewer of Col. Burrard's paper. Mr. Fisher now supposes the mountain mass not supported solely by the root immediately beneath it, but partly by the effect of the crust below the Siwalik rock of the plains being depressed by 15,000 ft. into the substratum. A third factor is thus brought into operation, namely a deficiency of mass underlying the plains. It is true it may be claimed that the deficiency is considered as part of the isostatic compensation of the visible Himalayan mass, and that Fisher's system does not introduce a third entity, but merely implies an irregular distribution of compensating masses. The whole deficiency equivalent to the surface excess, instead of lying directly below the latter, is, in part, displaced horizontally to below the plains. But the elimination of part of the deficiency below the visible range has the effect of altering the variation between deflections at the foot of the slope and at the south edge of the plain by only 2″, whereas the differential effect of this deficiency of mass, when transferred to the subcrust under the plains, is 8″. The significant fact is not so much the reduction of deficiency below the mountain range as the location of a deficiency under the plains between the foot of the slope and the southern station of observation. In Fisher's hypothesis this is the important feature which brings about a more rapid variation of deflections than follows from the assumption of simple compensation.

The results of the calculation upon the second hypothesis give 20″ as the variation of deflection between Dehra Dun and Kaliana, with an average deflection of 12″, against the observed 30″ and 16″. The calculated variation and average deflection for the interval between the foot of the hills and the southern edge of the plains are, respectively, 24″ and 10″, the observed values being 43″ and 16″. The differences between Fisher's quantities, based on the second hypothesis, and those observed, approach, on an average, 35 per cent. of the observed values.

Both hypotheses, that of simple and that of general compensation, fail to give results in accord with observation, when Fisher's numerical values are used. In his second hypothesis his assumption of a three-mile depression of the crust is inadequate. As pointed out by Col. Burrard in his paper, to explain Himalayan deflections by a hidden synclinal, we must assume the latter to be seventy to eighty miles wide and six miles deep under Siliguri, seven miles south of the foot of the slope, and two miles deep under Jaljaiguri, thirteen miles south of Siliguri, the rock composing the synclinal basin to have a density of 2·7, and the sediment filling the synclinal to have a density of 1·9. As Col. Burrard says, it is doubtful whether the density of sediment, when under a pressure of a vertical column six miles high, would remain as small as 1·9; any increase in its value will require the depth of the supposed synclinal to be increased.

In connection with Fisher's investigation, there is an interesting point. Putting aside his computed figures, we see that both he and Burrard agree in considering that the observed facts cannot be explained by only the visible Himalayan mass and its vertically underlying root. Both investigators are forced to conclude the existence of a third factor, a source of negative attraction under the plains at the foot of the hills. Fisher prefers to adopt the idea of deficiency extending under a relatively wide belt of the crust due to the depression of the latter into the liquid substratum, the outer surface of this depressed tract being brought up to sea-level by the deposition of the Siwalik beds and alluvium. This hypothesis leads to the assumption of very doubtful values of some of the unknown quantities, as has been shown above. Burrard's hypothesis differs from Fisher's in that he would localise the deficiency in a rift in the crust subsequently filled in by deposits.

H. M. COWIE.

Dehra Dun, U.P., India, April 3.

SURELY Col. Burrard and Major Cowie have misread the review; it did not dismiss Col. Burrard's speculations, but pointed out that he had himself dismissed, with what appeared to be inadequate examination, an hypothesis which seemed fully capable of explaining the facts. The sentence which has elicited their letters was intended to refer solely to the memoir under review, and had no application to other publications by the same author. The memoir did not, in fact, contain any detailed investigation of an hypothesis which, if tested numerically and in its completeness, appears to be at least as capable of affording an explanation of the facts as that propounded by Col. Burrard. The reviewer may point out that the limited amount of space at his disposal compelled the omission of reference to many points of which he was well aware, and had fully considered, but in view of the publication of these letters he may be permitted to amplify the argument of the paragraph in the review which has called them forth.

Mr. Fisher's investigation assumes an isostasy by flotation, and, what is an almost inevitable consequence, that the flotation is not confined to the area of the range, but that, as an iceberg has generally an under-water extension helping to support the visible mass, so the lighter "crust" under the plains is borne down into the denser "substratum" or "subcrust" by the weight of the mountain range. This interpretation is in accord with the evidence of the pendulum, which shows that the defect of gravity under the mountains is continued under the plain, and only gradually decreases with increasing distance from the range; it is also in accord with conclusions drawn by the Geological Survey long before the observations of variations in the force of gravity and of deflection of the plumb-line in the neighbourhood of the foot of the hills were published, and the constants used by Mr. Fisher, so far as they are special to the Himalayas, were taken from these reports.

According to the hypothesis, a station near the edge of the hills, such as Kurseong, would be affected (1) by the positive attraction of the visible masses; (2) the negative attraction of the "root" or downward thickening of the "crust" into the "substratum"; (3) by the negative attraction of the submerged portion of the "crust" under the plains, replacing denser "substratum"; and (4)—though Mr. Fisher did not separately consider this—by the negative attraction of the alluvial deposit of the plain, the mean density of which is less than that of average rock. Of these (1) is the same whatever hypothesis of isostasy is adopted; (2), it appears from Mr. Hayford's investigation of the effect of an isostasy produced by compensation limited to a ten-mile stratum, between twenty-five and thirty-five miles depth from the surface, would somewhat increase the deflection at a station situated on the edge of the hills (*e.g.* Kurseong), and make but little alteration at a station twenty or thirty miles out in the plain (*e.g.* Jalpaiguri); (3) and (4) would both produce their maximum effect at a station situated like Kurseong, and have comparatively little influence at one situated like Jalpaiguri. Here we have three separate corrections, all working in the same direction, and all attaining their maximum at the same station, and it is not inconceivable that together they might afford an explanation of the peculiarities noticed by Col. Burrard.

It is obviously useless, at the present stage of our knowledge, to enter into detailed calculations of an imaginary range, but some approximate calculations made by the reviewer indicate that the increase in the difference of deflection as between Kurseong and Jalpaiguri due to (2) would be of the order of 4″, to (3) of the order of 8″, and to (4) of not less than 9″, or a total increase in the calculated difference of deflections amounting to more than 21″, as compared with Col. Burrard's unexplained anomaly of 30″. These figures have no value, except as indicating that there is another hypothesis, besides that of the "rift," which would account for a change in the amount of deflection near the foot of the range, of the same character and order of magnitude as that actually observed.

It must be added that this explanation can only be taken as applying to the Himalayas; the conditions in the Vindhya are entirely different and require to be considered apart.

THE REVIEWER.